

Preliminary Evaluation of the AFWA-NASA (ANSA) Blended Snow-Cover Product over the Lower Great Lakes Region

DOROTHY K. HALL¹, JAMES L. FOSTER¹, GEORGE A. RIGGS², RICHARD E.J. KELLY³,
JANET Y.L. CHIEN⁴ & PAUL M. MONTESANO²

ABSTRACT

The Air Force Weather Agency (AFWA) – NASA (ANSA) blended-snow product utilizes EOS standard snow products from the Moderate-Resolution Imaging Spectroradiometer (MODIS) and the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) to map daily snow cover and snow-water equivalent (SWE) globally. We have compared ANSA-derived SWE with SWE values calculated from snow depths reported at ~1500 National Climatic Data Center (NCDC) co-op stations in the Lower Great Lakes basin. Our preliminary results show that conversion of snow depth to SWE is very sensitive to the choice of snow density (we used either 0.2 or 0.3 as conversion factors). We found overall better agreement between the ANSA-derived SWE and the co-op station data when we use a snow density of 0.3 to convert the snow depths to SWE. In addition, we show that the ANSA underestimates SWE in densely-forested areas, using January and February 2008 ANSA and co-op data. Furthermore, apparent large SWE changes from one day to the next may be caused by thaw-re-freeze events, and do not always represent a real change in SWE. In the near future we will continue the analysis in the 2006-07 and 2007-08 snow seasons.

INTRODUCTION

A blended-snow product (Fig. 1) has been developed jointly by the U.S. Air Force Weather Agency (AFWA) and the Hydrospheric and Biospheric Sciences Laboratory at NASA / Goddard Space Flight Center. A detailed description of the product, called the AFWA – NASA (ANSA) blended-snow product, may be found in Foster et al. (in press). The product utilizes the Moderate-Resolution Imaging Spectroradiometer (MODIS) standard snow-cover product (Hall and Riggs, 2007) and the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) standard snow-water equivalent (SWE) product (Kelly et al., 2004) to map daily snow cover and SWE globally. The objective of this work is to study the capability of the ANSA product to map SWE in the Lower Great Lakes region for the 2007-08 winter.

¹ Hydrospheric and Biospheric Sciences Laboratory, NASA/Goddard Space Flight Center, Greenbelt, Md. 20771.

² SSAI, Inc., Lanham, Md. 20706

³ Department of Geography, University of Waterloo, Waterloo, Ontario, Canada.

⁴ Consultant.

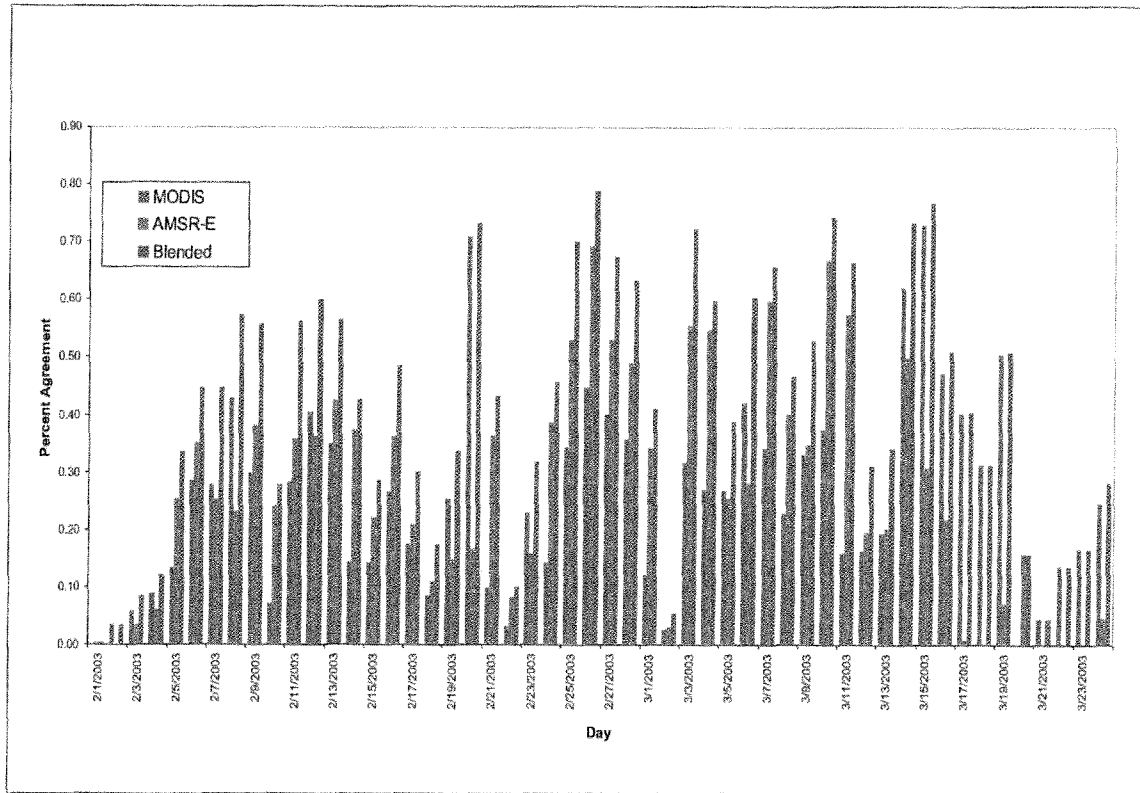


Figure 2. Relationship of the Percent of Agreement of the ANSA product, and the MODIS and AMSR-E input products, alone, as compared to ground truth for the lower Great Lakes region for mapping snow-cover extent in 2003. The AMSR-E contribution (green) becomes more important in late February during periods of cloudiness when MODIS cannot map the snow. When the sky is clear, MODIS (red) is the primary instrument to map snow cover in the ANSA algorithm (after Hall et al., 2007).

METHODOLOGY

For the present work we used National Climatic Data Center (NCDC) co-op station data from the winter of 2007 – 2008 in the Lower Great Lakes region, to compare with ANSA-derived SWE (Fig. 3). Co-op snow depth data were interpolated to develop a daily map (see sample map in Fig. 4) and then converted to SWE using two different conversion factors: 0.2 and 0.3 (representing snow density estimates of 0.2 and 0.3 g / cm³, respectively). (Since the exact snow density was unknown, we converted snow depth to SWE using two different snow densities which are reasonable for the conditions and time of year.) Difference maps were then constructed to permit evaluation of the differences in SWE derived from ANSA vs. station data.

RESULTS & DISCUSSION

Maps in Figs. 5a & 5b show the difference between the interpolated co-op data compared to the ANSA SWE on a cell-by-cell basis. The blue colors indicate that the ANSA underestimates SWE as compared to station data, and the pink colors indicate that ANSA overestimates SWE. The areas of best agreement are shown in neutral colors.

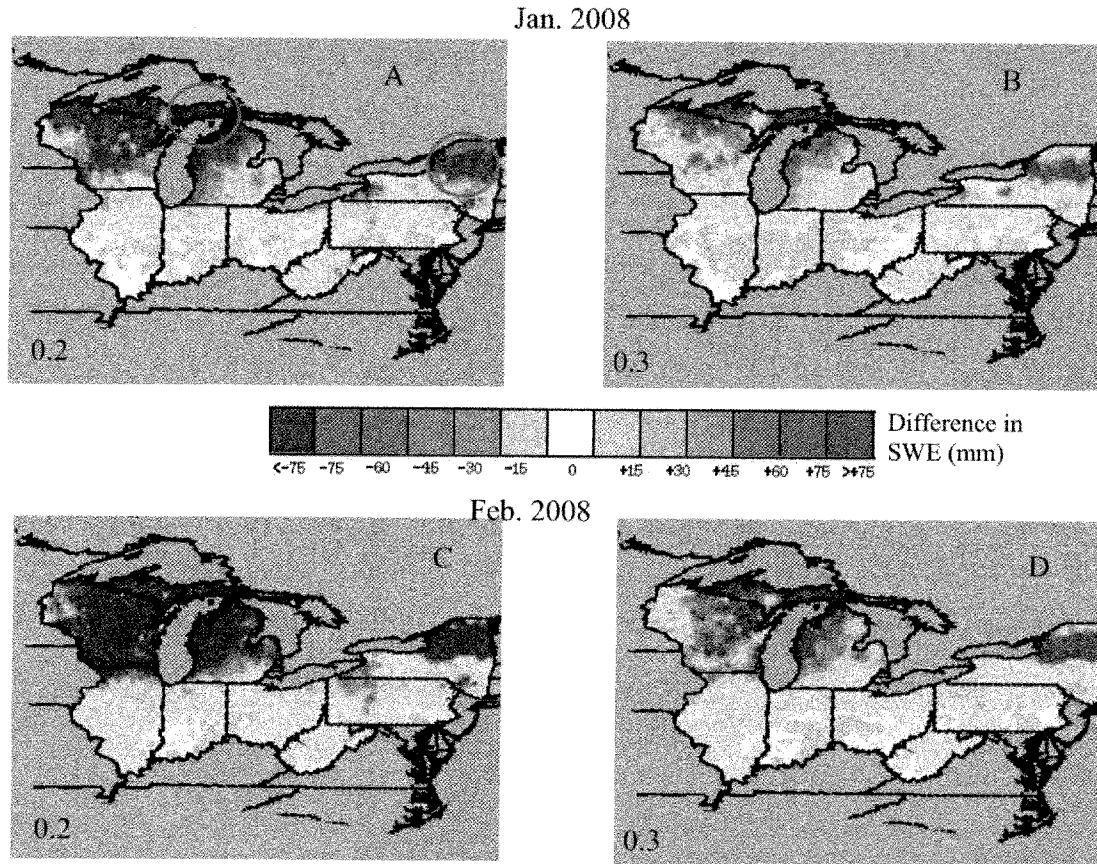


Figure 5. Mean difference between AMSR-E and station-derived SWE for January (A & B) and February 2008 (C & D) using 0.2 conversion factor (A & C), and 0.3 conversion factor (B & D). Conversion factors are used to convert co-op station snow-depths to SWE and are based on snow density. If snow density is not known, it must be assumed. This demonstrates the importance of knowing the snow density, for the calculation of SWE.

Snow density – conversion of density to SWE. In January and February of 2008, ANSA underestimates SWE in densely-forested areas such as in the Upper Peninsula of Michigan and in the Adirondacks in New York State by up to ~75 mm (see red circles in Fig. 5a). Even when using its forest-fraction adjustments, passive-microwave algorithms may still underestimate SWE in dense forests.

In this work, we addressed the question, “What snow density should be used to convert the co-op snow depths to SWE?” In both the January and February 2008 average SWE difference maps (Figs. 5a & 5b), there is overall better agreement when we use a snow density of 0.3 to convert the

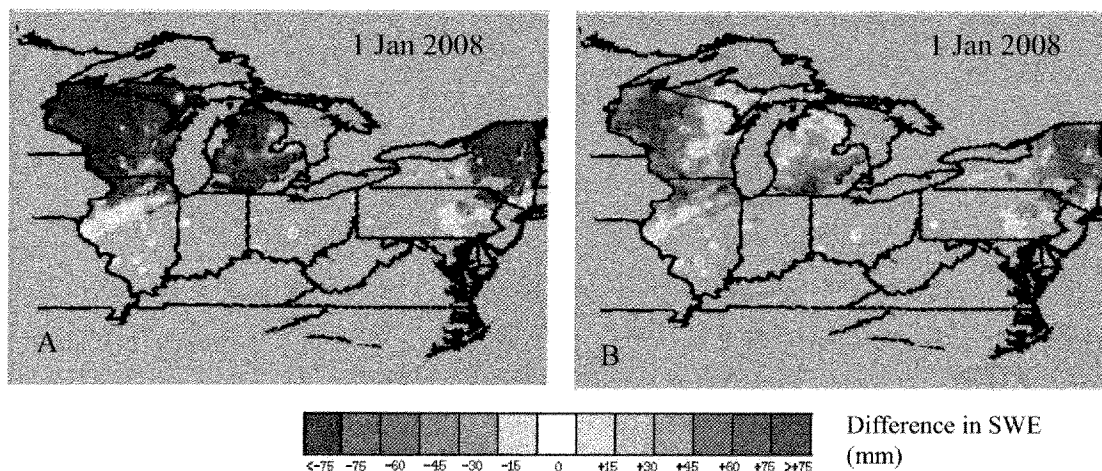


Figure 7. Mean difference between AMSR-E and station-derived SWE for 1 January 2008 using a conversion factor of 0.2 (A). In (B), the mean monthly bias is subtracted from each cell in the difference map, and is shown in (A). In these images, the non-snow-covered areas are shown in green.

Figure 7 shows the mean difference between AMSR-E and station-derived SWE for 1 January 2008 using a conversion factor of 0.2 (Fig 7A). Conversion factors are used to convert co-op station snow depths to SWE and are based on snow density. In Fig. 7B, the mean monthly bias, calculated from the daily differences between the ANSA-derived and co-op-derived SWE, is removed from each cell of the difference map shown in Fig. 7A.

CONCLUSIONS AND FUTURE WORK

We have examined the ability of the preliminary ANSA blended-snow product to measure SWE in the Lower Great Lakes region of the U.S. Results demonstrate that the ANSA underestimates SWE in dense forests, a known limitation of passive-microwave SWE algorithms.

Estimation of snow density is needed to convert the co-op station data to SWE values, so that ANSA SWE can be compared with “ground truth.” For our study area, use of a conversion factor of 0.3 (corresponding to a snow density = 0.3 g / cm^3) provides overall better agreement between ANSA and co-op SWE for both January and February 2008. This illustrates that a dynamic method of calculating snow density in a passive-microwave SWE algorithm would likely result in improved SWE estimates from microwave sensors.

Rapid changes in ANSA-derived SWE can occur such as are seen in Wisconsin between 9 and 10 January 2008. A change in snow conditions due to a thaw-re-freeze event may have caused erroneous AMSR-E SWE determination on 10 January 2008. We conclude this because the co-op data do not show an obvious increase in snow depth and SWE between these two days, but they do show air temperatures that support a thaw-refreeze event.

We calculated the average monthly bias (difference between co-op-derived SWE and AMSR-E SWE) from the daily maps from 1 – 31 January 2008. Those values, on a cell-by-cell basis, were subtracted from the AMSR-E SWE values for each day of January 2008. Results show an improvement in agreement between the co-op station-derived and AMSR-E SWE after the monthly bias was removed.